U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

5.4.7 RESIDUAL HEAT REMOVAL (RHR) SYSTEM

REVIEW RESPONSIBILITIES

Primary - Reactor Systems Branch (RSB)

Secondary - None

I. AREAS OF REVIEW

The residual heat removal (RHR) system is used in conjunction with the main steam and feedwater systems (main condenser), or the reactor core isolation cooling (RCIC) system in conjunction with the safety/relief valves in a boiling water reactor (BWR), or auxiliary feedwater sytem in conjunction with the atmospheric dump valves in a pressurized water reactor (PWR) to cool down the reactor coolant system following shutdown. Parts of the RHR system also act to provide low pressure emergency core cooling and are reviewed as described in SRP Section 6.3. Some parts of the RHR system also provide containment heat removal capability and are reviewed as described in SRP Section 6.2.2. The review by RSB is to ensure that the design of the RHR system is in conformance with General Design Criteria 2, 4, 5, 19, and 34.

Both PWRs and BWRs have RHR systems which provide long-term cooling once the reactor coolant temperature has been decreased by the main condenser, RCIC, or auxiliary feedwater systems. In both types of plants, the RHR is typically a low pressure system which takes over the shutdown cooling function when the reactor coolant system (RCS) temperature is reduced to about 300°F. Although the RHR system function is similar for the two types of plants, the system design are different.

The RHR system in PWRs takes water from the RCS hot legs, cools it, and pumps it back to the cold legs or core flooding tank nozzles. The suction and discharge lines for the RHR pumps have appropriate valving to assure that the low pressure RHR system is always isolated from the RCS when the reactor coolant pressure is greater than the RHR system design pressure. The heat removed in the heat exchangers is transported to the ultimate heat sink by the component cooling water or service water system. In PWRs, the RHR system is also used to fill, drain, and remove heat from the refueling canal during refueling operations, to circulate coolant through the core during plant startup prior to RCS pump operation, and in some to provide an auxiliary pressurizer spray.

The RHR system in BWRs is typically composed of four subsystems. The containment heat removal and low pressure emergency core cooling subsystems are discussed in SRP Sections 6.2.2 and 6.3. The shutdown cooling and steam condensing (via RCIC) subsystems are covered by this SRP section. These subsystems make use of the same hardware, consisting of pumps, piping, heat exchangers, valves, monitors, and controls. In the shutdown cooling mode, the BWR RHR system can also be used to supplement spent fuel pool cooling. As in the PWR, the low pressure RHR piping is protected from high RCS pressure by isolation valves.

The steam condensing mode of RCIC operation in BWRs (when included in the plant design) provides an alternative to the main condenser or normal RCIC mode of operation during the initial cooldown. Steam from the reactor is transferred to the RHR heat exchangers where it is condensed. The condensate is piped to the suction side of the RCIC pump. The RCIC pump returns the condensate to the reactor vessel. The heat removed in the heat exchangers is transported to the ultimate heat sink by the service water system.

Other means of removing decay heat in the event that the RHR system is inoperable have been proposed for some BWRs. These approaches use some of the piping that is used for the steam condensing mode of RCIC. These approaches are also covered by this SRP section.

The reactor coolant temperatures and pressure must be decreased before the low pressure RHR system can be placed in operation; therefore, the review of the decay heat removal function must consider all conditions from shutdown at normal reactor operating pressure and temperature to the cold depressurized condition. RSB reviews the requirements for reliability and capability of removing decay heat identified in NUREG-0660 (II.E.3.2 and II.E.3.3), NUREG-0718 (II.B.7), and NUREG-0737 (III.D.1.1). With respect to the staff review for compliance with Branch Technical Position RSB 5-1 (Ref. 5), the Auxiliary Systems Branch (ASB), Chemical Engineering Branch (CMEB), and RSB effort is divided as follows:

1. For BWRs, the RSB reviews the processes and systems used in the cooldown of the reactor for the entire spectrum of potential reactor coolant system pressures and temperatures during decay heat removal.

2. For PWRs, the RSB reviews the approach used to meet the functional requirements of BTP RSB 5-1 with respect to cooldown to the conditions permitting operation of the RHR system. Since an alternate approach to that normally used for cooldown may be specified, the reviewers identify all components and systems used. The CMEB has primary review responsibility for the review of the pertinent portions of the CVCS (SRP Section 9.3.4). The ASB, as part of its primary review responsibility for SRP Sections 10.3 and 10.4.9 reviews the atmospheric dump valves and the source for auxiliary feedwater, respectively, for conformance to BTP RSB 5-1. The RSB reviews the pressurizer relief valve and ECCS, if used. In addition, the RSB reviews the tests and supporting analysis concerning

mixing of borated water and cooldown under natural circulation as required in BTP RSB 5-1.

3. For both PWRs and BWRs, the ASB reviews the component cooling or service water systems that transfer decay heat from the RHR system to the ultimate heat sink as part of its primary review responsibility for SRP Sections 9.2.1 and 9.2.2.

4. The RSB reviews the design and operating characteristics of the RHR system with respect to its shutdown and long-term cooling function. Where the RHR system interfaces with other systems (e.g., RCIC system, component cooling water system) the effect of these systems on the RHR system is reviewed. Overpressure protection provided by the valving between the RCS and RHR system is also reviewed.

In addition, the Reactor Systems Branch will coordinate evaluations of other branches that interface with the overall review of the RHR system as follows: The Containment Systems Branch verifies that portions of the RHR system penetrating the containment barrier are designed with acceptable isolation features to maintain containment integrity for all operating conditions including accidents as part of its primary review responsibility for SRP Section 6.2.4; The Structural and Geotechnical Engineering Branch (SGEB) determines the acceptability of the design analysis, procedures and criteria used to establish the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena such as safe shutdown earthquake (SSE), the probable maximum flood (PMF), and tornado missiles as part of its primary review responsibility for SRP Sections 3.3.1, 3.3.2, 3.5.3, 3.7.1 thru 3.7.4, 3.8.4 and 3.8.5. The Materials Engineering Branch (MTEB) verifies that inservice inspection requirements are met for system components as part of its primary review responsibility for SRP Section 6.6 and, upon request, verifies the compatibility of the materials of construction with service conditions as part of its primary review responsibility for SRP Section 6.1. The Mechanical Engineering Branch (MEB) determines that the components, piping and structures are designed and tested in accordance with applicable codes and standards as part of its primary review responsibility for SRP Sections 3.9.1 through 3.9.3. The MEB also determines the acceptability of the seismic and quality group classifications for system components as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2 The effects of pipe breaks inside and outside of containment, such as pipe whip and jet impingement, are reviewed by MEB and ASB as part of their primary review responsibilities for SRP Sections 3.6.2 and 3.6.1, respectively. The MEB also reviews adequacy of the inservice testing program of pumps and valves as part of its primary review responsibility for SRP Section 3.9.6. The Procedures and Systems Review Branch (PSRB) reviews the proposed preoperational and startup test programs to confirm that they are in conformance with the intent of Regulatory Guide 1.68 as part of its primary review responsibility for SRP Section 14.2. The PSRB also has primary review responsibility for Task Action Plan items II.K.1 (C.1.10) of NUREG-0737 (OLs only) and I.C.6 of NUREG-0718 (CPs only) regarding procedures to ensure that system operability status is known. The ASB reviews flood protection as part of its primary review responsibility for SRP Section 3.4.1. The ASB identifies the structures systems and components to be protected against externally generated missiles and reviews the adequacy of protection against such missiles as part of its primary review responsbility for SRP Section 3.5.1.4 and 3.5.2. The ASB also reviews protection against internally generated missiles both inside and outside of containment as part of its primary review responsibility for SRP Sections 3.5.1.1 and 3.5.1.2. The Power Systems Branch (PSB) identifies the safety-related electrical loads and determines that power systems supplying motive or control power for the RHR system meet acceptable criteria and will perform these intended functions during all plant operating and accident conditions as part of its primary review responsibility for SRP Sections 8.1, 8.2, 8.3.1, and 8.3.2. The Instrumentation and Control Systems Branch (ICSB), as part of its primary review responsibility for SRP Sections 7.1 and 7.4 reviews the instrumentation and control systems for the RHR system to determine that it will perform its design function as required and conform to all applicable acceptance criteria. The ICSB also reviews the provisions taken to meet GDC 19 with respect to equipment outside of the control room for hot and cold shutdown. The Radiological Assessment Branch (RAB) has primary review responsibility for SRP Section 12.1 through 12.5 including Task Action Plan items II.B.2 of NUREG-0737 and NUREG-0718 which involve a radiation and shielding design review and corrective actions taken to ensure adequate access to vital areas and protection of safety equipment (CPs and OLs). The review for Fire Protection, Technical Specifications, and Quality Asurance are coordinated and performed by the CMEB, Standardization and Special Projects Branch (SSPB) and Quality Assurance Branch (QAB) as part of their primary review responsibility for SRP Sections 9.5.1, 16.0 and 17.0, respectively.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP Section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

The Reactor Systems Branch acceptance criteria are based on meeting the requirements of the following regulations:

A. General Design Criterion 2 with respect to the seismic design of systems, structures and components whose failure could cause an unacceptable reduction in the capability of the residual heat removal system. Acceptability is based on meeting position C-2 of Regulatory Guide 1.29 or its equivalent.

B. General Design Criterion 4, as related to dynamic effects associated with flow instabilities and loads (e.g., water hammer).

C. General Design Criterion 5 which requires that any sharing among nuclear power units of structures, systems and components important to safety will not significantly impair their safety function.

D. General Design Criterion 19 with respect to control room requirements for normal operations and shutdown, and;

E. General Design Criterion 34 which specifies requirements for a residual heat removal system.

Specific criteria necessary to meet the requirements of General Design Criteria 2, 4, 5, 19, and 34 are as follows:

1. The system or systems are to satisfy the functional, isolation, pressure relief, pump protection and test requirements specified in Branch Technical Position RSB 5-1.

2. In order to meet the requirements of General Design Criterion 4 (Ref 11), design features and operating procedures shall be provided to prevent damaging water hammer due to such mechanisms as voided pump discharge lines, water entrainment in steam lines and steam bubble collapse.

3. Interfaces between the RHR system and RCIC and component or service water systems should be designed so that operation of one does not interfere with, and provides proper support (where required) for, the other. In relation to these and other shared systems (e.g., emergency core cooling and containment heat removal systems), the RHR system must conform to GDC 5.

4. The requirements for the reliability and capability of removing decay heat under the following Task Action Plan items must also be satisfied:

   a. Meeting Task Action Plan item II.E.3.2 of NUREG-0660 which involves systems reliability. NRR will conduct a generic study to assess the capability and reliability of shutdown heat removal systems under various transients and degraded plant conditions including complete loss of all feedwater. Deterministic and probabilistic methods will be used to identify design weaknesses and possible system modifications that could be made to improve the capability and reliability of these systems under all shutdown conditions. (CPs and OLs). Specific requirements will be based on the results of this study.

   b. Meeting Task Action Plan item II.E.3.3 of NUREG-0660 which involves a coordinated study of shutdown heat removal requirements. An effort to evaluate shutdown heat removal requirements in a comprehensive manner is required, thereby permitting a judgment of adequacy in terms of overall system requirements. As part of this project, NRR will conduct a study to assess the desirability of and possible requirement for a diverse heat-removal path, such as feed and bleed, particularly if all secondary-side cooling is unavailable. The NRC staff will work with the recently established ACRS Ad Hoc Subcommittee on this matter to develop a mutually acceptable overall study program. (CPs and OLs). Specific requirements will be based on the results of this study.

   c. Meeting Task Action Plan item II.B.8 of NUREG-0718 (Ref. 7) which involves description by the applicants of the degree to which the designs conform to the proposed interim rule on degraded core accidents. (CPs only)

   d. Meeting Action Plan item III.D.1.1 of NUREG-0737 (Ref. 8) and NUREG-0718 (Ref. 7) which involves primary coolant sources outside of containment (CPs and OLs).

5. When the RHR system is used to control or mitigate the consequences of an accident, it must meet the design requirements of an engineered safety

feature system. This includes meeting the guidelines of Regulatory Guide 1.1 regarding net positive suction head.

III. REVIEW PROCEDURES

The procedures below are used during the construction permit (CP) review to assure that the design criteria and bases and the preliminary design as set forth in the Preliminary Safety Analysis Report meet the acceptance criteria given in subsection II.

For operating license (OL) reviews, the procedures are utilized to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the Final Safety Analysis Report. The OL review also includes the proposed technical specifications, to assure that they are adequate in regard to limiting conditions of operation and periodic surveillance testing.

As noted in subsections I and II, the RSB review for PWRs is limited to the low pressure - low temperature RHR system. For BWRs, the review is to include all of the systems used to transfer residual heat from the reactor over the entire range of potential reactor coolant temperatures and pressures. The following steps are to be applied by the reviewer for the appropriate systems, depending on whether a PWR or BWR is being reviewed. These steps should be adapted to CP or OL reviews as appropriate.

1. Using the description given in the applicant's Safety Analysis Report (SAR), including component lists and performance specifications, the reviewer determines that the system(s) piping and instrumentation are such to allow the system(s) to operate as intended, with or without offsite power and given any single active component failure. This is accomplished by reviewing the piping and instrumentation diagrams (P&IDs) to confirm that piping arrangements permit the required flow paths to be achieved and that sufficient process sensors are available to measure and transmit required information. A failure modes and effects analysis (or similar system safety analysis) provided in the SAR is used to determine conformance to the single failure criterion.

2. Using the comparison tables of SAR Section 1.3, the RHR system is compared to designs and capacities of such systems in similar plants to see that there are no unexplained departures from previously reviewed plants. Where possible, comparisons should be made with actual performance data from similar systems in operating plants.

3. From the system description and P&IDs, the reviewer determines that the isolation requirements of Branch Technical Position RSB 5-1 (Ref. 5) are satisfied.

4. The reviewer determines that the RHR system design has provisions to prevent damage to the RHR pumps in accordance with Branch Technical Position RSB 5-1 (Ref. 5). The reviewer checks the isolation valves in the suction line for potential closure, NPSH requirements, pump runout, and potential loss of miniflow line during pump testing. If operator action is required to protect the pumps, the reviewer evaluates the instrumentation required to alert the operator and the adequacy of the time frame for operator action.

5. The RHR systems is reviewed to evaluate the adequacy of design features that have been provided to prevent damaging water (steam) hammer due to such mechanisms as voided discharge lines, water entrainment in steam lines and steam bubble collapse. For systems with a water supply above the discharge lines, voided lines are prevented by proper vent location and filling and venting procedures. The vents should be located for ease of operation and testing on a periodic basis. If the normal alignment of suction valves is to a source below the highest level of the pump discharge lines (e.g., the suppression pool for RHR systems of BWRs) back leakage through the pump discharge check valves will result in line voiding.

   Proper vent location and filling and venting procedures are still needed. In addition, a special keep-full system with appropriate alarms is needed to supply water to the discharge lines at sufficiently high pressure to prevent voiding. Operating and maintenance procedures shall be reviewed by the applicant to assure that adequate measures are taken to avoid water hammer due to voided line conditions.

   For RHR systems of BWRs which use the steam condensing mode of operation, the evaluation should include consideration of water hammer due to (a) water entrainment in the steam supply line during startup, (b) formation of steam bubbles in the RHR system pump discharge lines and heat exchangers resulting from leakage past valves in the steam supply line, and (c) water entrainment in the discharge line of the pressure relief valve used to prevent overpressurization of the system during operation in the steam condensing mode.

6. Using the system process diagrams, P&IDs, failure modes and effects analysis, and component performance specifications, the reviewer determines that the system(s) has the capacity to bring the reactor to conditions permitting operation of the RHR system in a reasonable period of time, assuming a single failure of an active component with only either onsite or offsite electric power available. For the purposes of this review, 36 hours is considered a reasonable time period. The ASB is responsible for the review of the initial cooldown phase for PWRs. Therefore, this review effort is to be coordinated with that branch. For the purposes of the review of both PWRs and BWRs, only the operation of safety grade equipment is to be assumed.

7. The cooldown function is to be reviewed to determine if it can be performed from the control room assuming a single failure of an active component, with only either onsite or offsite electric power available. Any operation required outside of the control room is to be justified by the applicant. Like Item 5, the initial cooldown for PWRs is to be reviewed by ASB.

8. By reviewing the system description and the P&IDs, the reviewer confirms the RHR system satisfies the pressure relief requirements of Branch Technical Position RSB 5-1 (Ref. 5).

9. By reviewing the piping arrangement and system description of the RHR system, the reviewer confirms that the RHR system meets the requirements of GDC 5 (Ref. 2) concerning shared systems.

10. The RSB reviewer contacts the ASB reviewer in conjunction with his review of the RHR system heat sink and refueling system interaction to interchange information and assure that the reviews are consistent with regard to the interfacing parameters. For example, the ASB review determines the maximum service or component cooling water temperature. The RSB reviewer then reviews the RHR system description to determine that this maximum temperature has been allowed for in the RHR system design.

11. The RSB reviewer contacts his counterpart in the ICSB to obtain any needed information from their review. Specifically, ICSB confirms that automatic actuation and remote-manual valve controls are capable of performing the functions required, and that sensor and monitoring provisions are adequate. The instrumentation and controls of the RHR system are to have sufficient redundancy to satisfy the single failure criterion.

12. The RSB reviewer contacts his counterpart in CSB so that the information needed concerning their reviews will be interchanged.

13. The RSB reviewer contacts his counterpart in PSRB to discuss any special test requirements and to confirm that the proposed preoperational test program for the RHR system is in conformance with the intent of Regulatory Guide 1.68.

14. The proposed plant technical specifications are reviewed to:

    a. Confirm the suitability of the limiting conditions of operation, including the proposed time limits and reactor operating restrictions for periods when system equipment is inoperable due to repairs and maintenance.

    b. Verify that the frequency and scope of periodic surveillance testing is adequate.

15. The reviewer contacts the SGEB reviewer to confirm that the systems employed to remove residual heat are housed in a structure whose design and design criteria provide adequate protection against wind, tornadoes, floods, and missiles, as appropriate.

16. For PWRs, the reviewer confirms that the auxiliary feedwater supply satisfies the requirements of Branch Technical Position RSB 5-1.

17. The RSB reviewer provides information to other branches in those areas where the RSB has a review responsibility that is not explicitly covered in steps 1-15 above. These additional areas of review responsibility include:

    a. Identification of engineered safety features (ESF) and safe shutdown electrical loads, and verification that the minimum time intervals for the connection of th ESF to the standby power systems are satisfactory.

    b. Identification of vital auxiliary systems associated with the RHR system and determination of cooling load functional requirements and minimum time intervals.

c. Identification of essential components associated with the main steam supply and the auxiliary feedwater system that are required to operate during and following shutdown.

18. The RSB review evaluates the applicant responses to the following Task Action Plan items:

    a. II.E.3.2 of NUREG-0660 (CPs and OLs)

    b. II.E.3.3 of NUREG-0660 (CPs and OLs)

    c. II.B.8 of NUREG-0718 (CPs only)

    d. III.D.1.1 of NUREG-0737 and NUREG-0718 (CPs and OLs)

IV. EVALUATION FINDINGS

The reviewer verifies that the SAR contains sufficient information and his review supports the following kinds of statements and conclusions, which should be included in the staff's Safety Evaluation:

For PWRs

The residual heat removal function is accomplished in two phases: the initial cooldown phase and the residual heat removal (RHR system) operation phase. In the event of loss of offsite power, the initial phase of cooldown is accomplished by use of the auxiliary feedwater system and the atmospheric dump valves. This equipment is used to reduce the reactor coolant system temperature and pressure to values that permit operation of the RHR system. The review of the initial cooldown phase is discussed in Section _____ of the SER. The review of the RHR system operational phase is discussed below. The residual heat removal (RHR) system removes core decay heat and provides long-term core cooling following the initial phase of reactor cooldown. The scope of review of the RHR system for the _____plant included piping and instrumentation diagrams, equipment layout drawings, failure modes and effects analysis, and design performance specifications for essential components. The review has included the applicant's proposed design criteria and design bases for the RHR system and his analysis of the adequacy of those criteria and bases and the conformance of the design to these criteria and bases.

The staff concludes that the design of the Residual Heat Removal System is acceptable and meets the requirements of General Design Criteria 2, 4, 5, 19, and 34. This conclusion is based on the following:

(1) The applicant has met the General Design Criterion 2 with respect to position C-2 of Regulatory Guide 1.29 concerning the seismic design of systems, structures and components whose failure could cause an unacceptable reduction in the capability of the residual heat removal system.

(2) The applicant has met the General Design Criterion 4 with respect to dynamic effects associated flow instabilities and loads (e.g., water hammer).

(3) The applicant has met the requirements of General Design Criterion 5 with respect to sharing of structure, systems and components by demonstrating that such sharing does not significantly impair the ability of the Residual Heat Removal System to perform it safety function including in the event of an accident to one unit, an orderly shutdown and cooldown of the remaining units.

(4) The applicant has met General Design Criterion 19 with respect to the main control room requirements for normal operations and shutdown and General Design Criterion 34 which specifies requirements for the residual heat removal system by meeting the regulatory position in Branch Technical Position RSB 5-1.

In addition, the applicant has met the requirements of the following Task Action Plan Items:

(1) Task Action Plan item II.E.3.2 of NUREG-0660 (Ref. 10) as it relates to systems capability and reliability of shutdown heat removal systems under various transients.

(2) Task Action Plan item II.E.3.3 of NUREG-0660 (Ref. 10) as it relates to a coordinated study of shutdown heat removal requirements.

(3) Task Action Plan item II.B.8 of NUREG-0718 (Ref. 7) as it relates to description by the applicants of the degree to which the designs conform to the proposed interim rule on degraded core accidents (CPs only).

(4) Task Action Plan item III.D.1.1 of NUREG-0737 (Ref. 8) and NUREG-0718 (Ref. 7) as they relate to primary coolant sources outside of containment (CPs and OLs).

For BWRs

The residual heat removal function is accomplished in two phases: the initial cooldown phase and a low pressure-temperature operation phase. In the event of loss of offsite electrical power, the initial cooldown phase is accomplished using the reactor core isolation cooling (RCIC) system and the safety/ relief valves. The low pressure-temperature mode of operation is usually accomplished by the residual heat removal (RHR) system. However, certain single failures can render the RHR system inoperative. In that event, two alternate systems that use components of the RCIC and RHR system are available to bring the reactor to cold shutdown conditions.

The scope of review of these systems for the _______ plant included piping and instrumentation diagrams, equipment layout drawings, failure modes and effects analysis, and design performance specifications for essential components. The review has included the applicant's proposed design criteria and design bases for these systems and his analysis of the adequacy of those criteria and bases and of the conformance of the design to these criteria and bases.

The staff concludes that the design of the Residual Heat Removal System is acceptable and meets the requirements of General Design Criteria 2, 4, 5, 19, and 34. This conclusion is based on the following:

(1) The applicant has met General Design Criterion 2 with respect to position C-2 of Regulatory Guide 1.29 concerning the seismic design of systems, structures and components whose failure could cause an unacceptable reduction in the capability of the residual heat removal system.

(2) The applicant has met the General Design Criterion 4 with respect to dynamic effects associated flow instabilities and loads (e.g., water hammer).

(3) The applicant has met the requirements of General Design Criterion 5 with respect to sharing of structures, systems, and components by demonstrating that such sharing does not significantly impair the ability of the Residual Heat Removal System to perform its safety function including in the event of an accident to one unit, an orderly shutdown and cooldown of the remaining units.

(4) The applicant has met General Design Criterion 19 with respect to the main control room requirements for normal operations and shutdown and General Design Criterion 34 which specifies requirements for the residual heat removal system by meeting the regulatory position in Branch Technical Position RSB 5-1.

In addition, the applicant has met the requirements of the following Task Action Plan Items:

(1) Task Action Plan item II.E.3.2 of NUREG-0660 as it relates to systems capability and reliability of shutdown heat removal systems under various transients.

(2) Task Action Plan item II.E.3.3 of NUREG-0660 as it relates to a coordinated study of shutdown heat removal requirements.

(3) Task Action Plan item II.B.8 of NUREG-0718 (Ref. 7) as it relates to description by the applicants of the degree to which the designs conform to the proposed interim rule on degraded core accidents (CPs only).

(4) Task Action Plan item III.D.1.1 of NUREG-0737 (Ref. 8) and NUREG-0718 (Ref. 7) as they relate to primary coolant sources outside of containment (CPs and OLs).

In addition to the above criteria, the acceptability of the RHR system may be based on the degree of design similarity with previously approved plants. Deviations from these criteria from other types of RHR systems (e.g., systems that are designed to withstand reactor coolant system operating pressure or systems located entirely inside containmnt) will be considered on an individual basis.

V. <u>IMPLEMENTATION</u>

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced BTP RSB 5-1, regulatory guides, NUREGs and implementation of acceptance criterion subsections II.B and II.2 is as follows:

(a) Operating plants and OL applicants need not comply with the provisions of this revision.

(b) CP aplicants will be required to comply with the provisions of this revision.

VI. <u>REFERENCES</u>

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

2. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems and Components."

3. 10 CFR Part 50, Appendix A, General Design Criterion 19, "Control Room."

4. 10 CFR Part 50, Appendix A, General Design Criterion 34, "Residual Heat Removal."

5. Branch Technical Position RSB 5-1, "Design Requirements of the Residual Heat Removal System," attached to SRP Section 5.4.7.

6. Regulatory Guide 1.29, "Seismic Design Classification."

7. NUREG-0718, "Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License."

8. NUREG-0737, "Clarification of TMI Action Plan Requirements."

9. Regulatory Guide 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Systems."

10. NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident."

11. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Missile Design Bases."

BRANCH TECHNICAL POSITION RSB 5-1
DESIGN REQUIREMENTS OF THE RESIDUAL HEAT REMOVAL SYSTEM

BACKGROUND

GDC 19 states that, "A control room shall be provided from which actions can be taken to operate the nuclear power unit under normal conditions. . ."

Normal operating conditions including the shutting down of a reactor; therefore, since the residual heat removal (RHR) system is one of several systems involved in the normal shutdown of all reactors, this system must be operable from the control room.

GDC 34 states that "Suitable redundance. . .shall be provided to assure that for onsite electrical power system operation (assuming offsite power is not available) and for offsite electrical power system operation (assuming onsite power is not available), the system safety function can be accomplished, assuming a single failure."

In most current plant designs the RHR system has a lower design pressure than the reactor coolant system (RCS), is located outside of containment and is part of the emergency core cooling system (ECCS). However, it is possible for the RHR system to have different design characteristics. For example, the RHR system might have the same design pressure as the RCS, or be located inside of containment. Plants which may have RHR systems that deviate from current designs will be reviewed on a case-by-case basis. The functional, isolation, pressure relief, pump protection, and test requirements for the RHR system are included in this position.

BRANCH POSITION

A. Functional Requirements

The system(s) which can be used to take the reactor from normal operating conditions to cold shutdown* shall satisfy the functional requirements listed below.

1. The design shall be such that the reactor can be taken from normal operating conditions to cold shutdown using only safety-grade systems. These systems shall satisfy General Design Criteria 1 through 5.

2. The system(s) shall have suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities to assure that for onsite electrical power system operation (assuming offsite power is not available) and for offsite electrical power system operation (assuming onsite power is not available) the system function can be accomplished assuming a single failure.

*Processes involved in cooldown are heat removal, depressurization, flow circulation, and reactivity control. The cold shutdown condition, as described in the Standard Technical Specifications, refers to a sub critical reactor with a reactor coolant temperature no greater than 200°F for a PWR and 212°F for a BWR.

3. The system(s) shall be capable of being operated from the control room with either only onsite or only offsite power available. In demonstrating that the system can perform its function assuming a single failure, limited operator action outside of the control room would be considered acceptable if suitably justified.

4. The system(s) shall be capable of bringing the reactor to a cold shutdown condition, with only offsite or onsite power available, within a reasonable period of time following shutdown, assuming the most limiting single failure.

B. RHR System Isolation Requirements

The RHR system shall satisfy the isolation requirements listed below.

1. The following shall be provided in the suction side of the RHR system to isolate it from the RCS.

   (a) Isolation shall be provided by at least two power-operated valves in series. The valve positions shall be indicated in the control room.

   (b) The valves shall have independent diverse interlocks to prevent the valves from being opened unless the RCS pressure is below the RHR system design pressure. Failure of a power supply shall not cause any valve to change position.

   (c) The valves shall have independent diverse interlocks to protec against one or both valves being open during an RCS increase above the design pressure of the RHR system.

2. One of the following shall be provided on the discharge side of the RHR system to isolate it from the RCS:

   (a) The valves, position indicators, and interlocks described in item 1(a) thru 1(c) above,

   (b) One or more check valves in series with a normally closed power-operated valve. The power-operated valve position shall be indicated in the control room. If the RHR system discharge line is used for an ECCS function, the power-operated valve is to be opened upon receipt of a safety injection signal once the reactor coolant pressure has decreased below the ECCS design pressure.

   (c) Three check valves in series, or

   (d) Two check valves in series, provided that there are design provisions to permit periodic testing of the check valves for leak tightness and the testing is performed at least annually.

C. Pressure Relief Requirements

The RHR system shall satisfy the pressure relief requirements listed below.

1. To protect the RHR system against accidental overpressurization when it is in operation (not isolated from the RCS), pressure relief in the RHR system shall be provided with relieving capacity in accordance with the ASME Boiler and Pressure Vessel Code. The most limiting pressure transient during the plant operating condition when the RHR system is not isolated from the RCS shall be considered when selecting the pressure relieving capacity of the RHR system. For example, during shutdown cooling in a PWR with no steam bubble in the pressurizer, inadvertent operation of an additional charging pump or inadvertent opening of an ECCS accumulator valve should be considered in selection of the design bases.

2. Fluid discharged through the RHR system pressure relief valves must be collected and contained such that a stuck open relief valve will not:

   (a) Result in flooding of any safety-related equipment.

   (b) Reduce the capability of the ECCS below that needed to mitigate the consequences of a postulated LOCA.

   (c) Result in a non-isolatable situation in which the water provided to the RCS to maintain the core in a safe condition is discharged outside of the containment.

3. If interlocks are provided to automatically close the isolation valves when the RCS pressure exceeds the RHR system design pressure, adequate relief capacity shall be provided during the time period while the valves are closing.

D. Pump Protection Requirements

The design and operating procedures of any RHR system shall have provisions to prevent damage to the RHR system due to overheating, cavitation or loss of adequate pump suction fluid.

E. Test Requirements

The isolation valve operability and interlock circuits must be designed so as to permit on line testing when operating in the RHR mode. Testability shall meet the requirements of IEEE Standard 338 and Regulatory Guide 1.22.

The preoperational and initial startup test program shall be in conformance with Regulatory Guide 1.68. The programs for PWRs shall include tests with supporting analysis to (a) confirm that adequate mixing of borated water added prior to or during cooldown can be achieved under natural circulation conditions and permit estimation of the times required to achieve such mixing, and (b) confirm that the cooldown under natural circulation conditions can be achieved within the limits specified in the emergency operating procedures. Comparison with performance of previously tested plants of similar design may be substituted for these tests.

F. Operational Procedures

The operational procedures for bringing the plant from normal operating power to cold shutdown shall be in conformance with Regulatory Guide 1.33. For pressurized water reactors, the operational procedures shall include specific procedures and information required for cooldown under natural circulation conditions.

G. Auxiliary Feedwater Supply

The seismic Category I water supply for the auxiliary feedwater system for a PWR shall have sufficient inventory to permit operation at hot shutdown for at least 4 hours, followed by cooldown to the conditions permitting operation of the RHR system. The inventory needed for cooldown shall be based on the longest cooldown time needed with either only onsite or only offsite power available with an assumed single failure.

H. Implementation

For the purposes of implementing the requirements for plant heat removal capabilitity for compliance with this position, plants are divided into the following three classes:

Class 1 - Full compliance with this position for all plants (custom or standard) for which CP or PDA applications are docketed on or after January 1, 1978. See Table 1 for possible solutions for full compliance.

Class 2 - Partial implementation of this position for all plants (custom or standard) for which CP or PDA applications are docketed before January 1, 1978, and for which an OL issuance is expected on or after January 1, 1979. See Table 1 for recommended implementation for Class 2 plants.

Class 3 - The extent to which the implementation guidance in Table 1 will be backfitted for all operating reactors and all other plants (custom or standard) for which issuance of the OL is expected before January 1, 1979, will be based on the combined I&E and DOR review of related plant features for operating reactors.

TABLE 1. POSSIBLE SOLUTION FOR FULL COMPLIANCE WITH BTP RSB 5-1 AND RECOMMENDED IMPLEMENTATION FOR CLASS 2 PLANTS

Design Requirements of BTP RSB 5-1	Process and [System or Component]	Possible Solution for Full Compliance	Recommended Implementation for Class 2 Plants (see Note 1)
I. Functional Requirement for Taking to Cold Shutdown a. Capability Using Only Safety Grade Systems b. Capability with either only onsite or only offsite power and with single failure (limited action outside CR to meet SF) c. Reasonable time for cooldown assuming most limiting SF and only offsite or only onsite power.	Long-term cooling [RHR drop line]	Provide double drop line (or valves in parallel) to prevent single valve failure from stopping RHR cooling function. (Note: This requirement in conjunction with meeting effects of single failure for long-term cooling and isolation requirements involve increased number of independent power supplies and possibly more than four valves).	Compliance will not be required if it can be shown that correction for single failure by manual actions inside or outside of containment or return to hot standby until manual actions (or repairs) are found to be acceptable for the individual plant.
	Heat removal and RCS circulation during cooldown to cold shutdown (Note: Need SG cooling to maintain RCS circulation even after RHR in operation when under natural circulation [steam dump valves].)	Provide safety-grade dump valves, operators, and power supply, etc. so that manual action should not be required after SSE except to meet single failure.	Compliance required.
	Depressurization (Pressurizer auxiliary spray or power-operated relief valves).	Provide upgrading and additional valves to ensure operation of auxiliary pressurizer spray using only safety-grade subsystem meeting single failure. Possible alternative may involve using pressurizer power-operated relief valves which have been upgraded. Meet SSE and single failure without manual operation inside containment.	Compliance will not be required if a) dependence on manual actions inside containment after SSE or single failure or b) remaining at hot standby until manual actions or repairs are complete are found to be acceptable for the individual plant.

TABLE 1. POSSIBLE SOLUTION FOR FULL COMPLIANCE WITH BTP RSB 5-1
AND RECOMMENDED IMPLEMENTATION FOR CLASS 2 PLANTS

Design Requirements of BTP RSB 5-1	Process and [System or Component]	Possible Solution for Full Compliance	Recommended Implementation for Class 2 Plants (see Note 1)
	Boration for cold shutdown [CVCS and boron sampling].	Provide procedure and upgrading where necessary such that boration to cold shutdown concentration meets the requirements of I. Solution could range from (1) upgrading and adding valves to have both letdown and charging paths safety grade and meet single failure to (2) use of backup procedures involving less cost. For example, boration without letdown may be acceptable and eliminate need for upgrading letdown path. Use of ECCS for injection of borated water may also be acceptable. Need surveillance of boron concentration (boronometer and/or sampling). Limited operator action inside or outside of containment if justified.	Same as above.
II. RHR Isolation	RHR System	Comply with one of allowable arrangements given.	Compliance required. (Plants normally meet the requirement under existing SRP Section 5.4.7).
III. RHR Pressure Relief			
Collect and contain relief discharge	RHR System	Determine piping, etc., needed to meet requirement to provide in design.	Compliance will not be required, if it is shown that adequate alternate methods of disposing of discharge are available.

TABLE 1. POSSIBLE SOLUTION FOR FULL COMPLIANCE WITH BTP RSB 5-1
AND RECOMMENDED IMPLEMENTATION FOR CLASS 2 PLANTS

Design Requirements of BTP RSB 5-1	Process and [System or Component]	Possible Solution for Full Compliance	Recommended Implementation for Class 2 Plants (see Note 1)
V. Test Requirement			
Meet R.G. 1.68. For PWRs, test plus analysis for cooldown under natural circulation to confirm adequate mixing and cooldown within limits specified in EOP.		Run tests confirming analysis to meet requirement.	Compliance required.
VI. Operational Procedure			
Meet R.G. 1.33. For PWRs, include specific procedures and information for cooldown under natural circulation.		Develop procedures and information from tests and analysis.	Compliance required.
VII. Auxiliary Feedwater Supply			
Seismic Category I supply for auxiliary FW for at least four hours at hot shutdown plus cooldown to RHR cut-in based on longest time for only onsite or only offsite power and assumed single failure.	Emergency Feedwater Supply	From tests and analysis obtain conservative estimate of auxiliary FW supply to meet requirement and provide seismic Category I supply.	Compliance will not be required, if it is shown that an adequate alternate seismic Category I source is available.

Note 1: The implementation for Class 2 plants does not result in a major impact while providing additional capability to go to cold shutdown. The major impact results from the requirement for safety-grade steam dump valves.